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INTENSIVE TROPIC FUNCTION TESTING.(U)
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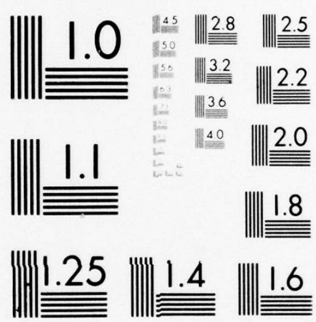

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INTENSIVE TROPIC FUNCTION TESTING

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INTRODUCTION:

Tropic testing of US Army materiel includes a storage phase designed to surface the adverse effects of the humid tropics. Failures are sometimes catastrophic, but are usually time dependent. Regulations such as AR 1000-1 (1) require that efforts be made to reduce Development Test time. Project Managers and DARCOM commodity commands have curtailed or foregone Development Tests because of excessive time/cost considerations. It was hypothesized that reducing test calendar time while increasing test functioning time, i.e., increasing the ratio of operational hours to calendar days may yield quicker and still valid test results for some categories of equipment. Large quantities of Reliability, Availability and Maintainability (RAM) data could be generated quickly for immediate analysis using standard RAM data analysis. A methodology investigation was conducted at the US Army Tropic Test Center to validate the intensified testing concept and reassess storage testing.

The tropic storage period results in a relatively long period of dormancy between data generation and the final production of test reports. Because the storage period represents a significant amount of calendar time, it had been repeatedly proposed that the storage phase be shortened or eliminated and that each test item be tested at an intensified functioning rate. Advocates of intensified functioning considered that the same quality of RAM data would be generated in a shorter calendar period. This is based on the assumption that number of operational hours is the only factor required for developing valid RAM data. The Tropic Test Center has observed materiel failures which occurred in the tropic storage phase of Development Tests. Examples of

such failures recently occurred during tests of the Forward Area Alert Radar (2), the OH-58A Helicopter (3), and the Modular Collective Protection Equipment (4). Although these failures were not identified with a single unique aspect of tropic exposure, they occurred during the tropic storage phase.

The US Army's standard 1.5 KW AC generator was selected as the test vehicle because it incorporated both electrical and mechanical components, it could be easily operated and had readily available maintenance support. The generators are high density items in the US Army supply system, i.e., available in large quantities, thus reducing project expenditures. The main advantage of using generators for this investigation was the capability to generate a large quantity of RAM data.

PROCEDURES:

The test site selected was an abandoned concrete pad in the Fort Clayton General Purpose test area in the humid tropics of the Canal Zone. Fifteen 1.5 KW AC generators were separated into three groups of five each (Figure 1), so that one group would be intensively functioned, the second would undergo a storage phase, and the third would simulate usage in the field. The generators were operated over a period of one year in the same test area using a single fuel source and equivalent variable power loads.

One group (Intensive Function Mode) was functioned at a rate of 16 hours per day for one year. The second group (Storage Mode) was functioned at a rate of four hours per day for 100 operational hours, after which the generators were placed in limited field storage as specified in the unit maintenance manuals (5). The storage period lasted six months, with an inspection at the end of the first three months. After the six-month storage, this group was returned to operation with the same usage schedule. The third group (Simulated Tactical Use Mode) was functioned at a rate of four hours per day for one year.

Power was drawn from each unit by a series of five 300-watt light bulbs which were so wired that the power drawn could be varied from 0 to 1500 watts in 300-watt stages. The load bank system is illustrated in Figure 2. Wired into the load banks and connected to a central control panel were meters which measured operational time, voltage output and voltage frequency. Figure 3 shows the control console with an oscilloscope attached for measuring the transients involved in load level changes. Load level changes took place every hour for a duration of 15 seconds, with the power draw change being from 900 to 1500 watts. Figure 4 shows the shunt resistor across which the stable

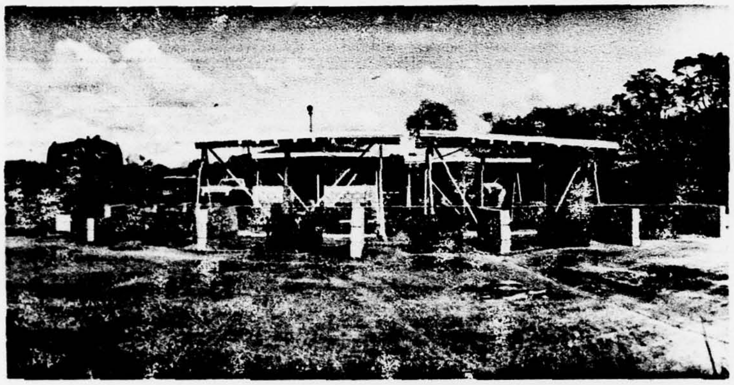

Figure 1. Test Site with Generators Mounted on a Concrete Pad

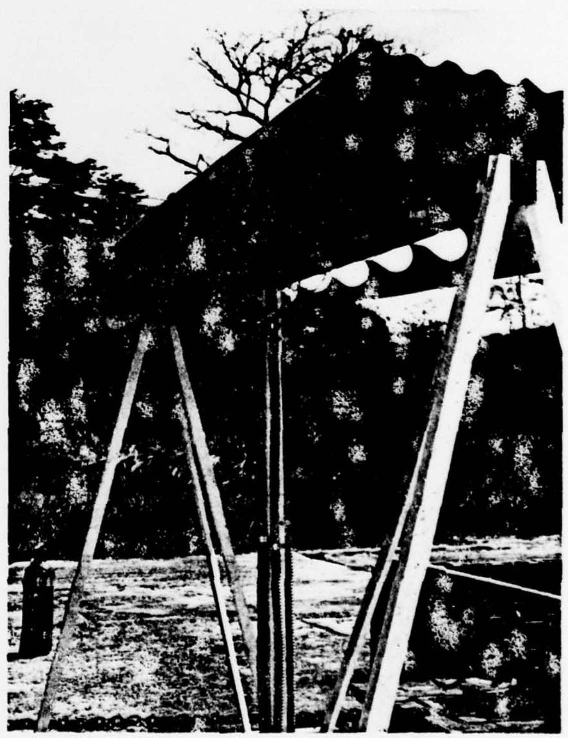

Figure 2. Load Bank System for Power Dissipation

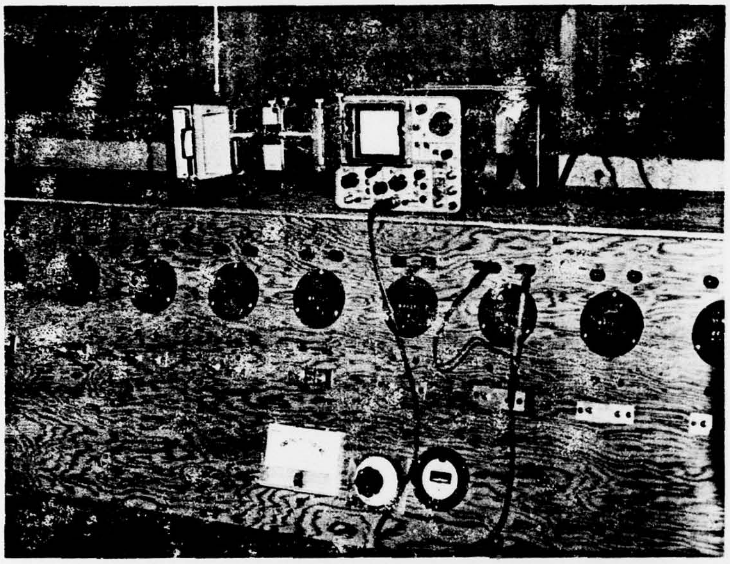

Figure 3. Control Console with Oscilloscope Attached

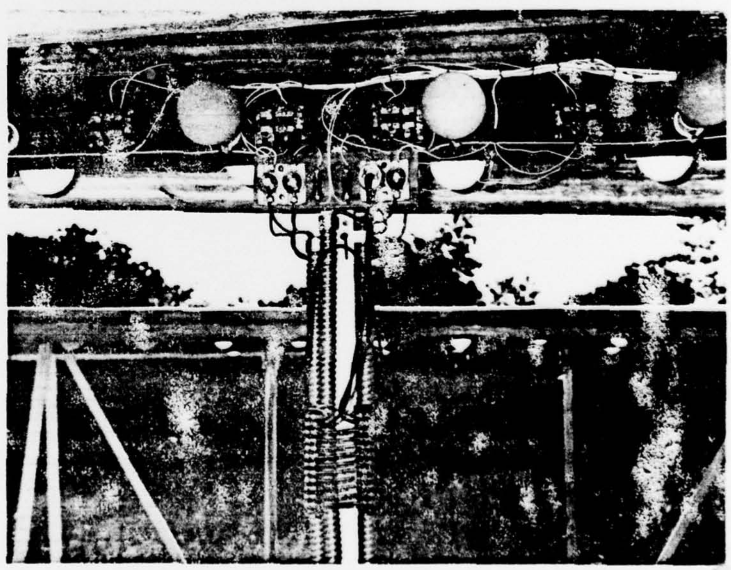

Figure 4. Shunt Resistor for Measuring Current Levels

and transient current levels were measured. Voltage and frequency levels for each generator were monitored and recorded on an hourly basis by an operator who reported malfunctions. Close monitoring was intended to identify the onset of a malfunction in order to initiate prompt maintenance action.

DISCUSSION OF RESULTS:

A summary of the data used in the analysis is presented in Tables I, II, and III. These tables present the basic data and computed RAM parameters for each of the functional modes and individual generators. Of these parameters, Mean Time Between Failures (MTBF) and Mean Time Between Maintenance Actions (MTBMA) are the most useful in assessing RAM performance. The discussion is confined to functional modes rather than individual generator performance. To establish a commonality, the data have been normalized to a per 1000 hours of operation basis.

In Tables I, II, and III there are five items of data per functional mode that lend themselves for RAM performance comparisons. These are the MTBF, MTBMA, Number of Chargeable System Failures per 1000 Hours (CSF/1000), Maintenance Actions per 1000 Hours (MA/1000) and Unscheduled Maintenance Time per 1000 Hours (UMT/1000). The MTBF is inversely proportional to CSF/1000 and the MTBMA is inversely proportional to MA/1000; therefore, only the values for the MTBF, MTBMA, and UMT/1000 are used as comparison parameters.

The MTBF was 243.0 hours for the Intensive Function Mode, 176.6 hours for the Storage Mode and 182.4 hours for the Simulated Tactical Use Mode. This indicates that the Intensive Function Mode had the longest operation period between failures, and that the Storage and Simulated Tactical Use Modes were similar, with the Storage Mode being slightly less. The second parameter, the MTBMA for the Intensive Function Mode, was 134.2 hours; the Storage Mode was 56.2 hours; and the Simulated Tactical Use Mode was 94.8 hours. The ranking for MTBMA is the same as for MTBF, except that the difference between the Storage Mode and the Simulated Tactical Use Mode is larger.

The UMT/1000 in Tables I, II, and III for the Intensive Function Mode was 2.8 hours, whereas the Storage and Simulated Tactical Use Modes were both 7.2 hours. Again, the Intensive Function Mode differs considerably from the other modes.

Additional computed RAM data are provided in Table IV for the functional modes. The MTBF and MTBMA data are also presented for convenience. Another useful RAM parameter is the Mean Time to Repair

TABLE I. SUMMARY OF INTENSIVE FUNCTION MODE DATA

Generator Number	Total Test Hrs	Number* Maint Actions	Number Chargeable System Failures	Number* Maint Act per 1000 Hrs	Number Chargeable System Failures per 1000 Hrs	Chargeable System Failure Time (Man-Hrs)	MTBF (Hrs)	MTBMA	Active Maintenance Time* Unscd (Man-Hrs)	Active Maintenance Time* Scd (Man-Hrs)	Active Maintenance Time* Total (Man-Hrs)	Unscd Maint Time per 1000 Hrs
1	878.6	6	4	6.8	4.6	3.6	219.7	146.4	3.6	3.0	6.6	4.1
2	2033.0	18	10	8.9	4.9	5.9	203.3	112.9	5.9	6.1	12.0	2.9
3	1867.5	17	10	9.1	5.4	5.7	186.8	109.9	5.7	6.1	11.8	3.1
4	2077.9	10	4	4.8	1.9	3.4	519.5	207.8	3.4	5.1	8.5	1.6
5	2133.1	16	9	7.5	4.2	6.7	237.0	133.3	6.7	4.6	11.3	3.1
Total	8990.1	67	37	–	–	25.3	–	–	25.3	24.9	50.2	–
Mean	1798.0	13.4	7.4	7.5	4.1	5.1	243.0	134.2	5.1	5.0	10.0	2.8
Standard Deviation	523.4	5.2	3.1	–	–	1.5	–	–	1.5	1.3	2.4	–

TABLE II. SUMMARY OF STORAGE MODE DATA

Generator Number	Total Test Hrs	Number* Maint Actions	Number Chargeable System Failures	Number* Maint Act per 1000 Hrs	Number Chargeable System Failures per 1000 Hrs	Chargeable System Failure Time (Man-Hrs)	MTBF (Hrs)	MTBMA	Unscd (Man-Hrs)	Scd (Man-Hrs)	Total (Man-Hrs)	Unscd Maint Time per 1000 Hrs
6	502.4	10	4	19.9	8.0	3.0	125.6	50.2	3.0	8.0	11.0	6.0
7	501.3	7	1	14.0	2.0	1.5	501.3	71.6	1.5	8.0	9.5	3.0
8	464.4	11	5	23.7	10.8	10.5	92.9	46.4	10.5	8.0	18.5	10.8
9	502.7	8	2	15.9	4.0	1.4	251.4	62.8	1.4	8.1	9.5	2.8
10	501.5	9	2	17.9	4.0	1.4	250.8	55.7	1.4	7.6	9.0	2.8
Total	2472.3	44	14	–	–	17.8	–	–	17.8	39.7	57.5	–
Mean	494.5	9.0	2.8	17.8	5.7	3.6	176.6	56.2	3.6	7.9	11.5	7.2
Standard Deviation	16.8	1.6	1.6	–	–	3.9	–	–	3.9	0.2	4.0	–

TABLE III. SUMMARY OF SIMULATED TACTICAL USE DATA

Generator Number	Total Test Hrs	Number* Maint Actions	Number Chargeable System Failures	Number* Maint Act per 1000 Hrs	Number Chargeable System Failures per 1000 Hrs	Chargeable System Failure Time (Man-Hrs)	MTBF (Hrs)	MTBMA	Unscd (Man-Hrs)	Scd (Man-Hrs)	Total (Man-Hrs)	Unscd Maint Time per 1000 Hrs
11	1024.1	5	1	4.9	1.0	1.0	1024.1	204.8	1.0	2.1	3.1	1.0
12	978.2	13	8	13.3	9.2	13.2	108.7	75.3	13.2	3.0	16.2	13.5
13	732.3	15	10	20.5	13.7	13.5	73.2	48.8	13.5	3.5	17.0	18.4
14	1004.0	11	5	11.0	5.0	4.0	200.8	91.3	4.0	4.0	8.0	4.0
15	1002.8	6	2	6.0	2.0	2.5	501.4	167.1	2.5	3.5	6.0	2.5
Total	4741.4	50	27	–	–	34.2	–	–	34.2	16.1	50.3	–
Mean	948.3	10	5.4	10.5	5.7	6.8	182.4	94.8	6.8	3.2	10.1	7.2
Standard Deviation	121.8	4.4	4.0	–	–	6.0	–	–	6.0	0.7	6.2	–

* Excludes oil changes

TABLE IV. SUMMARY OF COMPUTED RAM DATA

1	Mean Time Between Failures	
	Test Modes	
	a. Intensive Function	243.0
	b. Storage	176.6
	c. Simulated Tactical Use	182.4
2	Mean Time Between Maintenance Actions	
	Test Modes	
	a. Intensive Function	134.2
	b. Storage	56.2
	c. Simulated Tactical Use	94.8
3	Mean Time To Repair	
	Test Modes	
	a. Intensive Function	0.0
	b. Storage	1.5
	c. Simulated Tactical Use	1.0
4	Mean Time To Repair Unscheduled Maintenance Actions	
	Test Modes	
	a. Intensive Function	0.7
	b. Storage	1.3
	c. Simulated Tactical Use	1.3
5	Maintenance Ratio	
	Test Modes	
	a. Intensive Function	0.006
	b. Storage	0.023
	c. Simulated Tactical Use	0.011
6	Maintenance Ratio For Unscheduled Maintenance Actions	
	Test Modes	
	a. Intensive Function	0.003
	b. Storage	0.007
	c. Simulated Tactical Use	0.007

(MTTR). It is a measure of the degree of difficulty in performing maintenance actions, and was obtained by dividing the total active maintenance time for that functional mode by the total number of maintenance actions. The MTTR involves all maintenance actions, scheduled and unscheduled. For the MTTR, the Intensive Function Mode is 0.7 hours, the Storage Mode is 1.3 hours, and the Simulated Tactical Use Mode is 1.0 hour. Again, the Intensive Function Mode has required less time for repair than either of the other modes. Another MTTR value is for Unscheduled Maintenance Actions which is concerned primarily with actions involving generator malfunctions. In this case the Intensive Function value is 0.7 while the Storage and the Simulated Tactical Use values are both 1.3. The Intensive Function Mode required about half the time of the other two functional modes. The two remaining parameters in Table IV are the Maintenance Ratio and the Maintenance Ratio for Unscheduled Maintenance Actions. These are computed by dividing the active maintenance time, either total or unscheduled, by the total operational hours of each functional mode. The Maintenance Ratio for the Intensive Function Mode was 0.006, the Storage Mode was 0.023, and the Simulated Tactical Use Mode was 0.011. In the Maintenance Ratio for Unscheduled Maintenance Actions, the results were Intensive Function Mode 0.003, Storage Mode 0.007, and Simulated Tactical Use Mode 0.007. Both types of Maintenance Ratios show that the Intensive Function Mode produces lower values than the other two functional modes, and again the Storage and Simulated Tactical Use Modes had equivalent values.

It was assumed that the computed data (Tables I, II, III, and IV) are measures of the degree of operational severity for each functional mode to permit the construction of an arbitrary matrix for comparative purposes. The matrix (Table V) was based on six parameters (MTBF, MTBMA, UMT/1000, MTTR, MTTR Unscheduled Maintenance Actions, and Maintenance Ratio for Unscheduled Maintenance Actions) selected from the previous tables. For each parameter, a numerical value of one was given to the functional mode that was considered least severe; the value of two was given for the median severity; and the value of three for the most severe. In the case of two modes being equal for a given parameter, a value of 1.5 or 2.5 was assigned to both depending on degree of severity. The data are summarized in Table V. For all six parameters the Intensive Function Mode was given the value of one for being least severe. For three (MTBF, MTBMA, and MTTR) of the six parameters, the Storage Mode was the most severe and for the other three parameters it was equal to the Simulated Tactical Use Mode in severity. The ranking from least to most severe was as follows: Intensive Function Mode, Simulated Tactical Use Mode and Storage Mode, with a proportionality of 1:2.3:2.8, respectively.

TABLE V. SEVERITY OF OCCURRENCE

TEST MODE	SOURCE: TABLES I, II AND III			SOURCE: TABLE IV			
	MTBF	MTBMA	Unscd Maint Time per 1000 Hrs	Mean Time to Repair	Mean Time to Repair Unscd Maint Actions	Maint Ratio for Unscd Maint Actions	Summary Of Rows
Intensive Function	1	1	1	1	1	1	6
Storage	3	3	2.5	3	2.5	2.5	16.5
Simulated Tactical Use	2	2	2.5	2	2.5	2.5	13.5

1 Least Severe Test
2 Median Severe Test
3 Most Severe Test

NOTE: If equal in value, then assigned value will be 1.5 or 2.5 based on severity rank.

Tables I, II, and III also provide information on individual generators so that questions may be asked concerning the types of malfunctions that occurred and major differences in the types of malfunctions. To examine these questions, Tables VI and VII were prepared to summarize the data in appropriate form. Table VI is a Summary of Unscheduled Maintenance Actions by type of maintenance action performed and time involved for each functional mode. The number of maintenance actions, in decreasing order, were carburetor, ignition and voltage regulator, regardless of functional mode. To establish a baseline for comparative purposes, Table VII presents Normalized Unscheduled Maintenance Actions. The scheduled maintenance actions were not considered because some involved work unique to each functonal mode. This table also includes the average time to perform each action. For carburetors, the Storage Mode had more actions per 1000 hours, thus more time charged per 1000 hours, but the actual time per action for all three modes was about the same. This indicates that similar types of maintenance actions were performed on the carburetors, regardless of the functional mode. However, voltage regulators in the Storage Mode, required the least actions per 1000 hours. The Time Charged per 1000 Hours for the voltage regulator, the Storage Mode is half way between the Intensive Function and the Simulated Tactical Use Modes. However, the Time per Action for the storage mode is the highest. This means that, although the frequency of maintenance actions was less on voltage regulators of the Storage Mode, the amount of time required for that action was greater. For the ignition category, it is found that the Storage Mode had the highest number of maintenance actions performed per 1000 hours but the Simulated Tactical Use Mode had the most time per action. Although the number of actions per 1000 hours for Intensive Function Mode ignition maintenance actions is similar to the other two modes, there is a major difference in its value for the Time Charged per 1000 Hours and also for the Time per Action. This indicates that there is a difference in the type and degree of difficulty involved in the ignition maintenance actions performed during the Intensive Function Mode when compared with the other two modes.

This discussion has dealt with examining the three functional modes by operational hours instead of by calendar time. Because operation hours are rapidly accumulated in the Intensive Function Mode and the Storage Mode involves a long dormant period, it was determined that biased data would result from comparing the two modes by calendar time. Although it is recognized that the Intensive Function Mode produces malfunctions rapidly in a much shorter calendar period and produces RAM data in a shorter time, the rate and types of failure produced differ in comparision with the other two test modes.

TABLE VI. SUMMARY OF UNSCHEDULED MAINTENANCE ACTIONS

Type Of Maintenance Action	Intensive Function		Storage Mode		Sim Tactical Use	
	Number Of Actions	Time Charged	Number Of Actions	Time Charged	Number Of Actions	Time Charged
Carburetor	14	11.5	7	6.0	6	7.1
Voltage Regulator	5	3.0	1	1.5	5	4.5
Ignition	11	7.6	4	4.7	6	10.1
Fuse Breaker	3	0.4	—	—	—	—
Valve	1	0.1	—	—	2	2.5
Frequency Meter and Converter	—	—	—	—	3	2.5
Miscellaneous	3	2.7	2	5.6	4	7.5
Total	37	25.3	14	17.8	26	34.2

TABLE VII. SUMMARY OF NORMALIZED UNSCHEDULED MAINTENANCE ACTIONS

TYPE OF MAINTENANCE ACTION	INTENSIVE FUNCTION			STORAGE MODE			SIMULATED TACTICAL USE		
	Unscd Maint Act per 1000 Hrs	Unscd Maint per 1000 Hrs	Time per Action (Hr)	Unscd Maint Act per 1000 Hrs	Unscd Maint per 1000 Hrs	Time per Action (Hr)	Unscd Maint Act per 1000 Hrs	Unscd Maint per 1000 Hrs	Time per Action (Hr)
Carburetor	1.6	1.3	0.8	2.8	2.4	0.9	1.5	1.5	1.0
Voltage Regulator	0.6	0.3	0.6	0.4	0.6	1.5	1.1	0.9	0.9
Ignition	1.2	0.8	0.7	1.6	1.9	1.2	1.3	2.1	1.7
Miscellaneous	0.3	0.3	0.9	0.8	2.3	2.8	0.8	1.6	1.9

CONCLUSIONS:

On the basis of the results of the investigation discussed herein, the following conclusions are offered:

1. In terms of test severity, as depicted by the RAM parameters analyzed, the Intensive Function Mode ranked the least severe, the Simulated Tactical Use Mode next, and the Storage Mode was the most severe.

2. Materiel items having electro-mechanical characteristics similar to the 1.5 KW AC generators and tested in an Intensified Function Mode will probably not produce higher failure rates than Storage or Simulated Tactical Use Modes.

3. Malfunctions which occurred were of similar nature for all three modes (i.e., carburetor, voltage regulator, and ignition); however, the time required to correct the malfunctions was less for the Intensive Function Mode.

4. Pertinence of the findings of this investigation should be explored for other materiel systems such as electronic and various weapon systems.

5. The need for a tropic storage phase in development testing is essential and is supported by results of this investigation. The optimum period for the storage phase requires further investigation.

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